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ScienceDirect

Procedia Manufacturing 3 (2015) 308 – 311

Procedia MANUFACTURING

6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015

Ergonomic investigation of interventional radiology

Kazuhiko Shinohara*

School of Health Sciences,Tokyo University of Technology, Nishikamata,Ohta-ku ,Tokyo, Japan

Abstract

Interventional radiology (IVR) refers to a variety of minimally invasive procedures using small-caliber catheters under fluoroscopic or ultrasound guidance for the treatment of vascular and digestive diseases. Common IVR applications include dilatation, occlusion, and selective cannulation of vessels and the digestive canal without open surgery. Indications for IVR are rapidly increasing. However, ergonomic problems of IVR for physicians have not been considered. Such ergonomic problems and countermeasures were investigated in this study. Ergonomic problems during hepatic arterial catheterization and placement of a stent in the digestive canal, two frequent IVR procedures, were investigated. Ergonomic problems of IVR, problems induced by X-ray protectors, inadequate working postures and asthenopia induced by the apparatus, impaired maneuverability and neuro-muscular fatigue forced by small caliber catheter for intra-vascular catheterization, lacks of intuitive usability and standardization the devices and instruction documents are revealed in this study. For the continued safe development of IVR, outstanding ergonomic and technological problems must be resolved. Potential solutions include the development of adequate holding and accessory devices for small-caliber devices, improved educational software, and head-mounted displays. Further analyses of the workflow and ergonomic medical device design with input from end users are also critical.

Peer-review under responsibility of AHFE Conference

Keywords: Intervetional radiology; Mnimally invasive treatments; Ergonomics

1. Introduction

Interventional radiology (IVR) refers to a variety of minimally invasive procedures using small-caliber catheters under fluoroscopic or ultrasound guidance for the treatment of vascular and digestive diseases. Common IVR applications include dilatation, occlusion, and selective cannulation of vessels and the digestive canal without open

* Corresponding author. Tel.:+81-3-6424-2184; fax. :+81-3-6424-2184.
E-mail address: kazushin@stf.teu.ac.jp

Peer-review under responsibility of AHFE Conference
doi:10.1016/j.promfg.2015.07.158

surgery. Indications for IVR are rapidly increasing. However, ergonomic problems of IVR for physicians have not been considered. Such ergonomic problems and countermeasures were investigated in this study.

2. Material and methods

Ergonomic problems during hepatic arterial catheterization and placement of a stent in the digestive canal, two frequent IVR procedures, were investigated (Fig. 1, Fig. 2).

3. Results

Common ergonomic problems of IVR:

1. Neuromuscular fatigue and perspiration due to heavy X-ray protectors, resulting in risk of slip and fall.
2. Inappropriate working postures imposed by unfavorable arrangement of imaging apparatus such as X-ray and ultrasonography systems and their displays.
3. Eyestrain due to dim lighting and impaired maneuverability of devices due to placement of the X-ray monitor.
4. Neuromuscular fatigue during small caliber catheter placement for intravascular catheterization.
5. Lack of intuitive usability and standardization of IVR devices and instruction manuals.

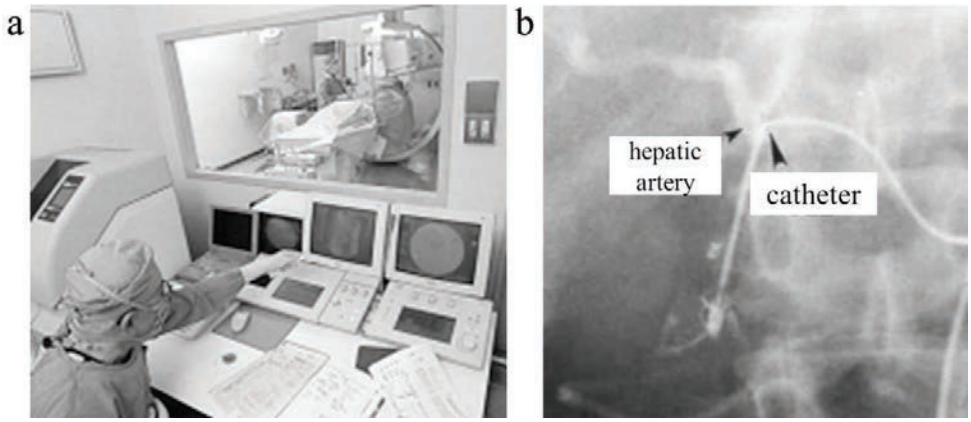

Fig. 1. (a) Scenes of IVR at the angiography room; (b) Intra-hepatic arterial catheterization by IVR.

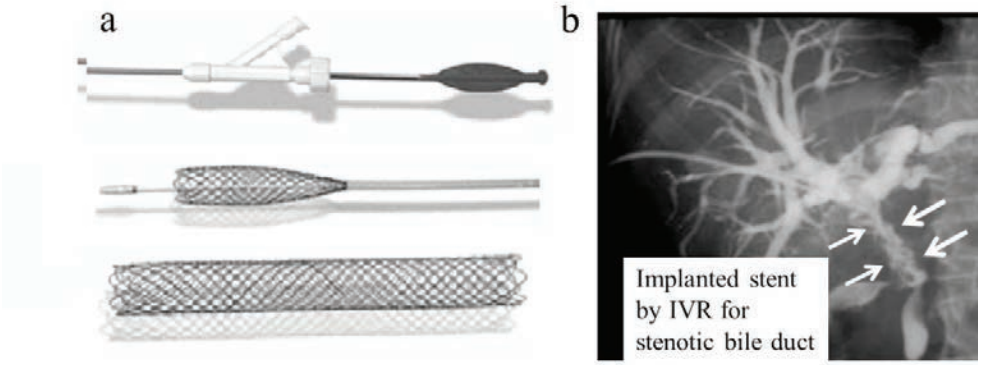

Fig. 2. (a) The stent device for stenotic digestive canal; (b) Implantation of stent for stenotic bile duct.

Fig. 3. X-ray protector and goggles for body, thyroid and eyes.

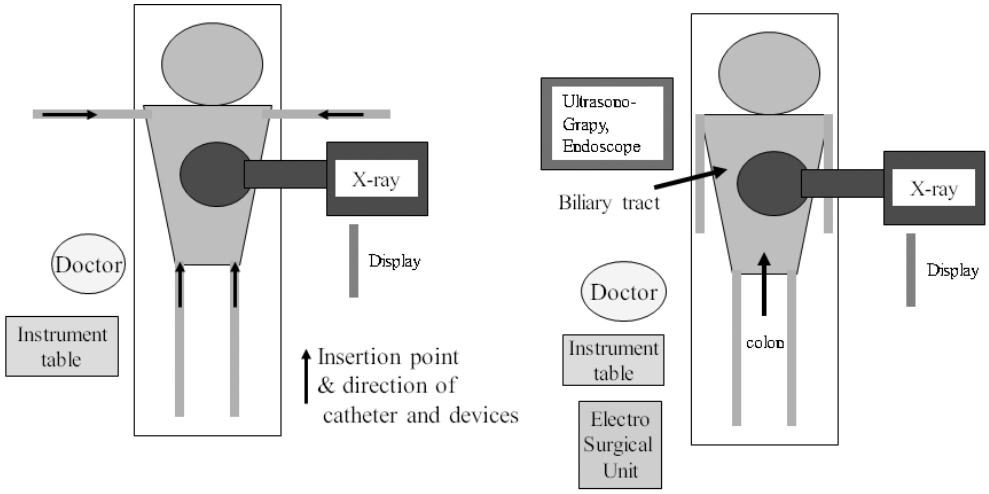

Fig. 4. Layout of Medical Devices and Main access points for IVR.

4. Discussion

Interventional radiology allows for minimally invasive treatments such as vessel dilatation and placement of stents, super-selective infusion embolization and drug administration in vessels, and selective treatment of tumors and abscesses by image-guided insertion of medical devices. As IVR obviates the need for open surgery, these techniques are now widely applied for treatment of brain, heart, hepatobiliary, and gastrointestinal diseases. Indeed, IVR is representative of minimally invasive treatments that include endoscopic surgery. Therapeutic devices and energy are delivered under the guidance of X-ray, ultrasound, or other imaging modalities. The accuracy and safety of IVR procedures are highly dependent on both the device used and the physician's technique. Development of devices for IVR applications are rapidly proceeding. However, ergonomic considerations for IVR physicians have been neglected except for radiation health management. Most IVR procedures are performed under X-ray fluoroscopy, so the physician must wear body X-ray protection that weighs more than 4 kg as well as protective goggles. This safety wear is a major cause of fatigue and perspiration, increasing the risk of accidents and cervico-omo-brachial syndrome. (Fig. 3).

The configuration of the X-ray apparatus, display, and operating table cannot be changed readily or arranged freely, so physicians must manipulate devices and gaze at imaging displays in ergonomically poor postures. As an example, physicians are forced to insert and manipulate catheters while twisting the body, neck, and wrist. Furthermore, most operations under X-ray fluoroscopy are conducted under dim lighting—a main cause of eyestrain—which may increase the risk of improper device manipulation during IVR (Fig. 4).

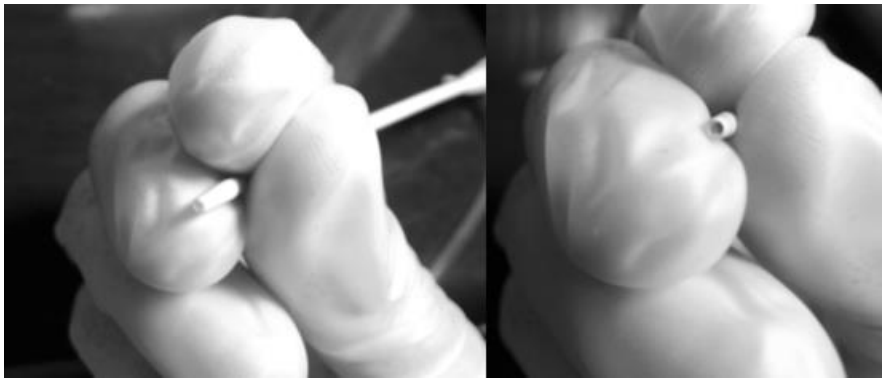

Fig. 5. Small caliber catheter for IVR.

As catheters and devices for IVR are delivered to the target lesion via blood vessels and the digestive canal, most are less than 2 mm in diameter. Physician must rotate, push, and pull these small caliber devices while wearing sterilized gloves. Fig.5. This is also a major cause of neuromuscular fatigue, which again may result in improper movement of catheters. [1] Moreover, there are no industry standards on ergonomic design and training on ways to minimize these risks. Also, the legibility and comprehensibility of user's manuals are generally unsatisfactory. These factors are all barriers to the use of IVR devices and increase the risk of malpractice with IVR treatment.

The development of remote manipulators for IVR using robotics technology is a promising solution to these ergonomic problems. Nonetheless, there are many technical and economic hurdles to widespread implementation of such systems for IVR compared with surgical robots like the "da Vinci" surgical system™. Problems of perspiration associated with heavy X-ray protectors can be improved by using cooling material and devices. However, the weight savings are limited by the need for X-ray protection. Inadequate working postures imposed by the inefficient placement of imaging apparatus can be improved by the development of therapeutic devices with integrated displays. Use of head-mounted displays that present X-ray and other images to physicians are another possible solution. However, ergonomics should also be considered in the use of head-mounted displays. Impaired maneuverability and neuromuscular fatigue due to manipulation of small caliber devices can be reduced by developing adequate aids and gloves that maintain friction and holding force. Fig.5. For improved usability of IVR devices and user's manuals, industry standards should be considered as well as more extensive use of audiovisual teaching material and tablet type PC terminals.

5. Conclusion

Ergonomic problems during IVR were analyzed in this study and potential solutions proposed. For the continued safe development of IVR, outstanding ergonomic and technological problems must be resolved. Potential solutions include the development of adequate holding and accessory devices for small-caliber devices, improved educational software, and head-mounted displays. Further analyses of the workflow and ergonomic medical device design with input from end users are also critical.

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